Summer School on
5G: ENABLING TECHNOLOGIES, OPPORTUNITIES AND RESEARCH CHALLENGES AHEAD
6 ECTS

Day 1		Monday July 1st
Introduction to 5G: Long story short	Luise	9-11
PHY-layer Technologies for 5G (i)	Moretti	11-13
PHY-layer Technologies for 5G (ii)	Bacci	14-16
Electromagnetic methodologies for 5G	Monorchio	16-18
Day 2		Tuesday July 2nd
Artificial Intelligence for 5G Networks and Applications	Renda	9-11
Cloud/Edge Computing for 5G Networks	Vallati	11-13
5G and UAV applications	Giordano	14-16
SDN and NFV in the 5G era	Virdis	16-18
Day 3		Wednesday July 3rd
End-to-end network programmability	Procissi, Lettieri	9-13
Optics for 5G networks	Andriolli	14-16
The role of 5G on Industrial IoT	Garroppo	16-18
Day 4		Thursday July 4th
System-level simulation and real-time emulation of 5G networks	Stea, Nardini	9-13
Security and privacy in 5G systems	Garroppo	14-16
Non-terrestrial networks for 5G	Giannetti	16-18
Day 5		Friday July 5th
5G as an enabler of digital transformation	XXXXX	9-11
Vehicle-to-Everything (V2X) Services in 5G and Beyond	Garroppo	11-13
Electromagnetic Systems for 5G Automotive Applications	Michel	14-16
Electronic circuits and systems for 5G Automotive V2X scenarios	Saponara	16-18

1. **Introduction to 5G: Long story short** - Prof. M. Luise

   - Communications: a Person's Fundamental Right
   - Mobile/Wireless Communications and the Internet
   - Generations of Mobile Networks: From 2G to 3G to 4G to 5G
   - Searching For Efficiency: the 5G 10 x 10 x 10 Equation
   - Challenges in 5G Deployment: where are we now?

2. **PHY-layer Technologies for 5G (I)** - Prof. M. Moretti

   - 5G propagation channel
   - NR numerology
   - Enhanced Mobile Broadband
   - Ultra-reliable low-latency communications
   - Massive connectivity

3. **PHY-layer Technologies for 5G (II)** - Prof. G Bacci

   - Multiple antenna technologies (MIMO, massive MIMO).
   - mmWave Communications.
   - Dense networks (small cells,…)

4. **Methodologies for electromagnetic propagation in 5G** - Prof. A. Monorchio

   - E.M. Propagation Phenomenology at 5G bands
   - Short introduction to high-frequency techniques
   - Ray Tracing procedure
   - Applications and validation
   - Limitations and efficiency improvement
   - Comparison with empirical propagation models
   - Phased Array Antenna modelling
   - Decoupling of antennas
   - E.M. field level evaluation

5. **Artificial Intelligence for 5G Networks and Applications** – Alessandro Renda

- A brief introduction to Artificial Intelligence
- Artificial Intelligence in 5G technology
- Artificial intelligence applications supported by 5G technology
- Future trends

6. **Cloud/Edge Computing for 5G Networks and Applications** – Prof. Carlo Vallati

- Cloud computing: general introduction to Cloud Computing and basic concepts. Virtualization as enabling technology for cloud computing.
- Mobile Edge Computing: general introduction to MEC as extension that moves computing and storage at the edge of the network.
- The role of MEC in 5G networks

7. **5G and UAV applications** - Prof. Stefano Giordano

- Space-based networks, Air-based Networks, Ground-based Networks
- UAV-assisted communications
- Cellular-connected UAVs
- Flying Ad Hoc Networks (FANETs)
- Aerial Hetnets; Combined UAV and D2D Communications
- Dynamic Deployment Ability
- UAV-Based Swarm Networks
- Low- and high-altitude platforms
- Energy harvesting in UAV Networks
- Computing Communication and Caching/Storage in the sky
- Network Softwarization and Virtualization in UAV Communications
- Networks in a box

8. **SDN and NFV in the 5G era** - Prof. A. Virdis

   - SDN Principles: Control- and data-plane Separation, SDN general architecture and components, Northbound and Southbound interfaces.
   - Open-SDN: the classical SDN view, flowtables, openflow, the role of the SDN controller
   - The evolution of SDN: from network management to SDN, alternative SDN views
   - Network softwarization and slicing: SDN architecture for 5G
   - NFV: virtual network functions and orchestration, architecture overview, relation with SDN

9. **End-to-end network programmability: from core switches to end hosts** – Prof. G. Procissi, Prof. G. Lettieri

   - From original SDN to programmable network data-plane
   - In-network computing: programmable switches and the the P4 language
   - P4 in practice: running a programmable software switch in an emulated network environment
   - End-host computing: in-kernel networking with extended Berkeley Packet Filter
   - (eBPF)eBPF in practice: programming simple applications on a Linux machine

10. **Optics for 5G networks** - Prof. Nicola Andriolli

    - Overview of fiber-optic transmission and networking
    - 5G-oriented optical networks
    - Optical interfaces for 5G radio access network
    - Optical technologies for 5G X-haul
    - Radio-over-fiber

11. **The role of Beyond 5G on Industrial IoT** - Prof. Rosario Garroppo

    - Classifications, Requirements and Performance Indicators of IIoT services.
    - Technologies and architectures for supporting IIoT URLL and Massive IoT Services.
    - Support for Time Sensitive Communications.
    - 5G Non-Public Networks and support for a 5G-LAN type service.
    - Technical Challenges for B5G-based IIoT services.

12. **System-level simulation and real-time emulation of 5G networks** - Prof. Giovanni Stea, Giovanni Nardini

- Introduction to discrete-event simulation
- Open-source tools to simulate 5G: link-level vs. application-level
- Introduction to the OMNeT++ framework
- Modelling the 5G protocol stack and network components
  - Overview of the Simu5G simulator
  - Simulating 5G network scenarios
- Fast prototyping of 5G applications
  - Configuring Simu5G as a real-time network emulator
  - Running real-time applications in emulated 5G networks

13. **Security and privacy in 5G systems** - Prof. Rosario Garroppo

- Security and privacy evolution in cellular networks.
- Privacy and security issues in 5G standard: main approaches, threats and challenges
- Reference to the security-by-design approach, authentication and subscriber's privacy.
- Open security issues and risks in the 5G echo-system.

14. **Non-terrestrial networks for 5G** - Prof. Filippo Giannetti

- Basics of radio wave propagation through the atmosphere
- Non-Terrestrial Communication Systems
- The Role of NTN Communications in 5G Ecosystem
- Radio Layer Issues
- Radio protocol issues
- Open Issues and Future Directions

15. **Vehicle-to-Everything (V2X) Services in 5G and** Beyond - Prof. Rosario Garroppo

- Classification and requirements of V2X services.
- V2X use-cases.
- IEEE and 3GPP Technologies for basic V2X services.
- 5G and B5G Architecture and technologies for supporting advanced V2X services.
- Technical Challenges of Advanced V2X.

16. **Electromagnetic Systems for 5G Automotive Applications** – Prof. A. Michel

- Sensors and Wireless Systems integrated on vehicles: applications and requirements
- Key performance parameters of Electromagnetic Systems for vehicular application
- Evolution of Electromagnetic Systems for Cellular Communication: from GSM to 5G and beyond
- Effect of vehicle on Electromagnetic System performance
- Challanges and future trends on Automotive Electromagnetic Systems for Cellular Communications

17. **Electronic circuits and systems for 5G Automotive V2X scenarios** - Prof. Sergio Saponara

- Introduction about HW enabling technologies for 5G
- RF/mmW transceiver circuits for 5G
- 5G digital baseband processors
- Safety and HW security for on-board 5G vehicle connectivity
- Circuit solutions for 802.11p WLAN and 5G C-V2X vehicle to everything connections
- Analysis of devices and application examples to autonomous and connected vehicles